WRP Technical Note HY-RS-3.1
August 1993

Hydrology and Hydraulic Design Criteria for the Creation and Restoration of Wetlands

PURPOSE: Hydrology is generally accepted as the single most important factor governing the successful establishment and maintenance of specific wetlands types and wetland processes. Long before the study of wetlands was a separate field of science, early scholars recognized the importance of hydrology in the establishment of wetland types and the attainment of wetland functions. Still, many wetland establishment or restoration projects fail because the proper hydrology and hydraulics needed to meet the project goals were not attained.

Failure to establish the correct hydrology can result in a different type of wetland than desired or mandated, no wetland, or a failure to achieve desired functions and the establishment of undesirable flora and fauna. This technical note provides hydrology and hydraulics informational background for four basic wetland types along with important considerations in developing functional design.

BASIC WETLAND TYPES: In the hydrogeomorphic classification for wetlands (Brinson, 1993), there are four basic wetland types; riparian (or riverine), fringe, depressional, and peatland. These are defined by geomorphic setting; however each has it's own unique hydrology. In addition, each type naturally lends itself to certain functions.

- Riparian. Riparian wetlands are those found along rivers and in river floodplains or basins. Because of their close association with rivers, the greatest source of water for these wetlands is from riverine flood flows usually following flooding of the associated river. Although flooding may be infrequent, flooding frequency and duration will largely determine the type of vegetation that occurs.

  A southern bottomland hardwood (BLH) forest or swamp, located along a river or stream, is a good example of how important flooding frequency is in relation to vegetative composition. Flooding tolerances of some common representative BLH trees are listed in Table 1.

Table 1.[1] Flooding Tolerance of Common BLH Tree Species

Cypress/Tupelo	6-8 months
Overcup Oak/Red Maple	4-6 months
Pin Oak/Sweet Gum	1-6 months
Cherrybark Oak/Willow Oak	1-3 months

[1] Fredrickson, L. H., and M. E. Heitmeyer, 1988. Waterfowl Use of Forested Wetlands of the Southern United States: An Overview. Chapter 22 in Waterfowl in Winter. 1988 University of Minnesota. Milton W. Weller ed. University of Minnesota Press, Minneapolis, MN.

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These plants cannot withstand flooding in excess of the listed values. If the hydrology of a river or stream in the BLH forest is changed by either damming the stream or changing land use around the stream and affecting runoff, plant composition in the forest will also change. In mildly affected systems this may shift the dominant tree species from pin oak to overcup oak. Yet, if the hydrology is drastically altered, as in the case of introducing dams or other control structures to hold nearly constant water levels, then the entire forest can be lost. Restoration of such a forest will be impossible, unless the appropriate hydrology is restored.

Riparian areas naturally function to attenuate flood flows. Peak flows are diminished as the water spreads out over the flood plain. As flood waters recede, the floodplain gradually releases its water. This results in flatter hydrographs and less downstream flooding. Likewise, most riparian wetlands are very effective sediment traps. Fast moving sediment laden flood flows slow down over the vegetated floodplain and drop a large portion of the sediment load. The removal of sediment also removes associated nutrients and toxicants such as herbicides and pesticides that typically attach themselves to the suspended sediment, resulting in improved downstream water quality.

Riparian areas tend to be sites for groundwater recharge during flood flows and sites for groundwater discharge during low river flows. Because of the normal pattern of flooding and sedimentation deposition in this type of wetland, groundwater discharge or recharge usually are minor components of the total water balance. Accumulated, fine organic sediments tend to seal the bottom of riparian areas preventing much interaction with underlying groundwater. In western areas, where sediments may be largely inorganic, the riparian wetland water balance may have a large groundwater component.

Many riparian areas produce large quantities of organic matter such as annual wetland plants or leaf litter. During flooding, this organic matter is transported to downstream waters by receding flood flows. This ability of wetlands to produce and export organic carbon is often referred to as the production export function.

- Fringe. Fringe wetlands are located along the edges of larger surface water bodies such as oceans or lakes. The fringe wetland is generally found within the fluctuation zone of rising and falling water levels from the main body of water. These wetlands may be in the tidal region of an estuary, between mean high and mean low water, along the edges of a large lake subject to wind induced seiches, or within the fluctuation zone of a reservoir where water level changes may be caused by the operation of the reservoir.

As with riparian wetlands, the hydrology of fringe wetlands is dominated by the larger source of water, in this case the lake, reservoir, estuary, or ocean. Direct inputs into the wetland system from rainfall, surface flows and groundwater interaction are subordinate influences. Viable wetland plant species will also be controlled by the larger source of water.

In estuaries, there is typically a predictable sinusoidal rise and fall of water due to rising and falling tides. In this environment, spartina marshes tend to dominate the landscape, occurring in the region between mean high and mean low water. There is predictable daily wetting and drying of the land that is necessary for the establishment of the salt marsh.

A combination of wind- and gravity-induced water movement can set up a sinusoidal movement of water in a lake, a process called a seiche. Large fresh water lakes with long fetches, are inclined to wind-induced seiching. A strong wind applied to a long fetch will pile up water on the

downwind side of the lake. This causes a hydraulic gradient across the lake. As the wind subsides, the force of gravity will cause the water to move back toward the other side of the lake, which now has a lower head. Since the shoreline of the lake is exposed to a similar, although less uniform or predictable water regime as the estuary, it is capable of supporting freshwater spartina and bulrush marshes.

Most reservoirs constructed by the U.S. Army Corps of Engineers (USACE) are used for flood control and water supply. To accomplish both these goals most reservoirs have operating (rule) curves similar to the one presented in Figure 1, for Grenada Lake in northern Mississippi.

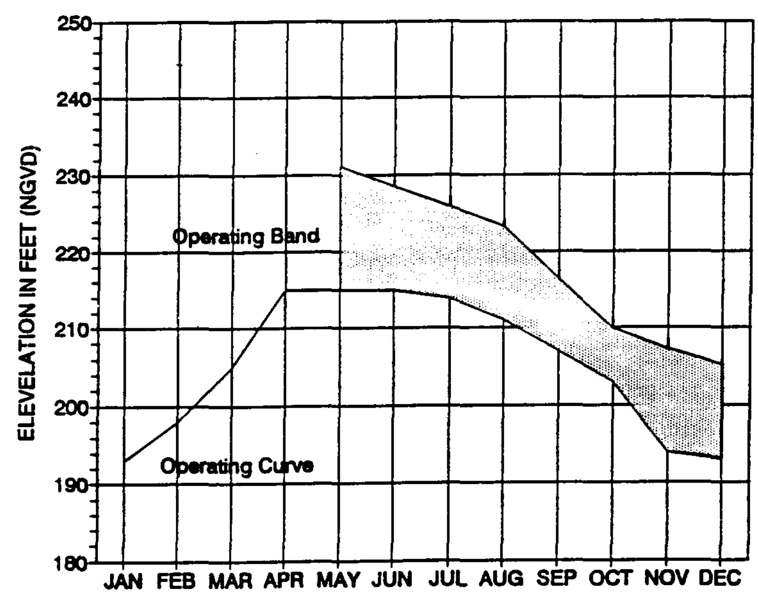

Figure 1. Grenada Lake rule curve*

* (from United States Army Corps of Engineers (USACE), Vicksburg District, 1989. Standing Instructions to the Project Manager for Water Control, Grenada Lake, Yazoo Basin)

As shown in the figure, the typical pattern of operation for the lake is to draw down the water level to conservation pool in late winter allowing heavy spring flows to be captured to prevent flooding. Water gradually released during the growing season provides water for irrigation. This type of operation exposes expansive mudflats on the lake floor and also provides an opportunity to establish large vegetated wetlands on the land lying between flood stage and conservation stage. However, because of the timing and magnitude of the water level fluctuations, establishing wetland vegetation in these areas is difficult.

The dominating hydrology of fringe wetlands is naturally suited for several functions. Fringe wetlands provide shoreline stabilization since the vegetation damps the magnitude of waves and currents. Similarly, this damping motion tends to reduce resuspension of sediments, improving water clarity and quality. If freshwater inflows must first pass through fringe wetlands before entering the lake or estuary, then significant sediment removal and water quality improvements can occur. The organic products of fringe wetlands are continually transported to the larger body

of water. This increases the net productivity of the larger water body. Likewise, the fringe wetland can use the larger body of water as a source of nutrients, increasing the productivity of the wetland. Fringe wetlands also provide an area for flood attenuation.

- Depressional. Depressional wetlands, unlike riparian and fringe wetlands, are a more self-contained system, with their own hydrology. Depressional wetlands occur in geologic land depressions. They can form on either steeply or mildly sloping landscapes, and often form at the junction of steep and mild slopes. Depressional wetlands can have one or more inlets and outlets or no inlet or outlet, commonly the case with prairie potholes. Because of this morphology, depressional wetlands depend on a variety of water sources.

  Prairie potholes occur in the plains states of North Dakota, South Dakota, Nebraska, etc. Since prairie potholes have no inlet or outlet, the hydrology of these systems is dominated by rainfall and evaporation. Prairie potholes typically occur in semi-arid regions, and therefore are dry most of the year. The potholes tend to fill during early summer rains. Some systems with a link to groundwater may fill during spring thaw. The vegetation in these systems has adapted to this hydrology and flourishes during wetting cycles, dying off and becoming dormant during the long, dry period.

  Depressional wetlands with inlets and outlets are very similar in hydrology and hydraulics to reservoirs. These wetlands occur in every climate and in every region of the country. The hydrology of each wetland is unique. This is probably the most frequently constructed type of wetland; and typically the goal of these construction projects is to create a freshwater marsh or wet meadow. The success of such projects hinges on establishing the proper hydrology for the plant species selected. Any number of water sources, runoff, groundwater, rainfall, and flood flows may be used. The only requirement is that the proper water budget and hydroperiod, meaning the duration of wetting, be established.

  Because of the amorphous quality of the hydrology for depressional wetlands, they can be used for a variety of functions and can often be driven to perform certain functions by altering the current hydrology. Isolated prairie potholes provide excellent breeding habitat for migratory waterfowl. However, due to their isolated nature, these wetlands usually do not perform hydrologic functions. They may function as a source of groundwater recharge, but this is typically insignificant due to their small size. Depressional wetlands with inlets and outlets, however, often perform many of the same functions as riverine and fringe wetlands. They can provide for flood attenuation, sediment retention, water quality improvements, and net production export to downstream water bodies. The type of hydrology present in the individual depressional wetland will determine if and to what degree it performs any or all of these functions. Particular functions can be achieved by altering the wetland hydrology.

- Peatland. Peatlands, often referred to as bogs or fens, are depressional wetlands in a special geomorphic setting, with special hydrology and thus, special vegetative and chemical composition. Peatlands are formed in regions of the world that have a water surplus. The water to most peatlands is provided by precipitation. However, peatlands usually occur where the water table is high and in contact with the peatland, even during dry conditions. This causes the peatland to be continually wet, allowing for the formation of peat producing mosses and trees.

  Generally, peatlands have little or no surface water component. Peatlands tend to be nutrient poor, and the water tends to be acidic, a factor affecting the vegetation and characteristics of this type of wetland.

As peat accumulates in the depression where the wetland has formed, the peatland may continue to grow and expand beyond its original boundaries. Peatlands may grow into other peatlands, forming huge complexes.

Because peatlands occur in such specific hydrologic conditions, they are not well suited for typical hydrologic and related water quality functions. Though peat is a highly marketable item in some regions of the world, the construction or restoration of a peatland would most likely be done for aesthetic or specific wildlife habitat purposes.

SPECIAL HYDRAULIC CONDITIONS OF WETLANDS: Although much of what is known about hydraulics is directly applicable to wetlands there are some characteristics of wetlands that require special consideration. Two of the most important issues are briefly discussed below.

- Shallow Water Depths. Wetlands, by definition, are shallow vegetated bodies of water. Most wetlands are one meter deep or less. This shallow water depth has the effect of increased frictional resistance to flow.

- Aquatic Vegetation. The presence of aquatic vegetation in a wetland increases the frictional resistance to flow. Because of the occurrence of very thick vegetation, this effect can be dramatic, producing roughness coefficients far exceeding any values found in typical hydraulic references.

  In addition, the presence of emergent aquatic vegetation has the effect of redistributing the frictional resistance to flow all along the water column, thus redefining the velocity gradients. Because of this effect, friction factors are no longer constant, and tend to decrease with increased depth. This effect is plant species and density dependent so that flow resistance changes during the year as plants develop and then die, and, on a larger time scale, with species succession. Shih and Rahi (1982) determined that the calculated Manning's roughness coefficient for a subtropical marsh varied from 0.16 to 0.55 over a depth of only 65 to 40 cm, and that the coefficient increased by a factor of three over the six month period from June to November. In addition, flow in wetlands is frequently in the transition zone between laminar and turbulent flow (Kadlec 1990). Because of these and other complications, simple application of flow equations such as Manning's equation will not yield valid results and more detailed analysis is required.

CONCLUSIONS: Before beginning a wetland establishment or restoration project, it is necessary to understand the four basic geomorphic wetland types and the accompanying hydrology and hydraulics, as well as the functions that each type can typically achieve. Next, the planner should closely study the geomorphology and hydrology of available sites. Hydrology can be determined by either collecting field data or conducting hydrologic model studies of the area.

With this knowledge, the planner can make realistic determinations as to the possible wetland types and functions that can be established. Understanding of wetland hydrology and related functions is essential in accomplishing successful restoration projects and avoiding undesirable results and consequences. Designing engineers should be aware of special considerations in wetland hydraulics and make compensations to account for the differences between wetlands and open channel or reservoir hydraulics.

REFERENCES:

Brinson, M. M. 1993. "A Hydrogeomorphic Classification for Wetlands," Technical Report WRP-DE-4, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Kadlec, R. H., 1990. Overland Flow in Wetlands: Vegetation Resistance. Journal of Hydraulic Engineering. Vol. 116 No. 5 American Society of Civil Engineers.

Shih, S. F., and G. S. Rahi, 1982. Seasonal Variations of Manning's Roughness Coefficient in a Subtropical Marsh. Trans., Am. Soc. of Agricultural Engrs., 25(1), 116-120.

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